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U.S. RELIANCE ON FOREIGN SOURCES IN MISSILE SPECIAL TEST EQUIPMENT MANUFACTURING

by

William J. Devlin

December, 1990

Thesis Advisor: Martin J. McCaffrey

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Many question the health and competitiveness of U.S. industry. In today's global markets we have seen U.S. dominance erode in several large industries. These industries include consumer electronics, automobiles and machine tools. When analyzing the nation's industrial base, one area of concern beyond final goods is the utilization of foreign sourced materials in domestic products. It was suggested that as much as 30 percent of the components in U.S. test equipment might be foreign sourced. The purpose of this study was to test that hypothesis, narrowing the scope to the manufacturing of production special test equipment (STE). As used here, production STE is that test equipment designed for and typically unique to a given production effort. A case study was done with the production STE of the HARM missile. This case study, coupled with the expert opinion of industry representatives, suggests only marginal

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dependence on foreign sourced materials in production STE.

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U.S. Reliance on Foreign Sources in Missile Special Test Equipment Manufacturing

by

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requirements for the degree of

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ABSTRACT

Many question the health and competitiveness of U.S. industry. In today's global markets we have seen U.S. dominance erode in several large industries. These industries include consumer electronics, automobiles and machine tools. When analyzing the nation's industrial base, one area of concern beyond final goods is the utilization of foreign sourced materials in domestic products. It was suggested that as much as 30 percent of the components in U.S. test equipment might be foreign sourced. The purpose of this study was to test that hypothesis, narrowing the scope to the manufacturing of production special test equipment (STE). As used here, production STE is that test equipment designed for and typically unique to a given production effort. A case study was done with the production STE of the HARM missile. This case study, coupled with the expert opinion of industry representatives, suggests only marginal dependence on foreign sourced materials in production STE.

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I. INTRODUCTION

A. BACKGROUND

The health and continued strength of the U.S. industrial base will play a significant role in the future security of the U.S., not only in military terms, but of equal importance, economic terms. Today, government officials and leaders of industry question the ability of America's industry to successfully compete in the global market place. Many of these same government and industry representatives question the ability of the nation's defense industrial base to meet the military hardware requirements of a surge or mobilization situation.

A definition of the nation's industrial base should not be necessary. The defense industrial base, in general terms, is comprised of those industries that provide the military goods and services to support peacetime as well as surge and mobilization requirements. The defense industries are generally thought of as those prime contractors that produce weapons systems such as tanks, aircraft and ships.

In fact, the defense industry also includes thousands of lower tier subcontractors that supply their products to the primes. There is often little distinction between a defense industry manufacturer and a non-defense industry manufacturer. Issues that affect one will invariably affect the other.

These issues include labor skills, materials availability, production capabilities and environmental concerns.

The general populace, not necessarily thinking in terms of industrial base, is well aware of the increasing influence of foreign producers in domestic markets. Recent years have seen an extraordinary shift in relative power and position of domestic manufacturers. Today, U.S. industries that dominated the world at one time, are fighting to retain portions of their former market shares. Others are fighting just to survive. The best known examples of industries that have experienced or are experiencing these changes include consumer electronics, automobiles and machine tools.

In addition to foreign produced final products making such progress against U.S. manufacturers, materials and components made abroad are also making advances. While the U.S. has pursued high technology industries, other countries, most notably Pacific Rim countries, have developed their resources and relative competence to compete in high volume, low technology industries. Here, many of these foreign competitors are able to capitalize on economies of scale and a large semi-skilled work force.

The reliance of U.S. manufacturers on foreign sourced materials is of particular concern today. In addition to anxieties over lost jobs and displaced U.S. workers, there is concern that as dependence on foreign sourced materials increases, so does the country's potential economic

vulnerability. Specifically, should the flow of foreign sourced materials be disrupted, undesired politico-economic consequences may follow.

B. RESEARCH OBJECTIVE

Foreign sourcing of materials used by U.S. industry is an area of increasing concern. Concurrent with declining industrial base capabilities there appears to be an increasing dependence on foreign sources for many of our industrial needs. In one significantly large industry, test equipment, an informal study had suggested that as much as 30 percent of the components within U.S. test equipment are produced by foreign manufacturers. [Ref. 1]

The intent of this research is to examine the components in special test equipment (STE) used by a single manufacturer in the production process, and to determine the extent of the foreign composition of that STE. This thesis will demonstrate an approach for identifying the geographic origin of the components within production STE, and hence the extent of dependence upon foreign sourced items in this critical field.

C. RESEARCH QUESTIONS

In an attempt to examine the extent and possible implications to the industrial base of foreign sourced materials in production STE, the following research questions are pertinent.

1. Primary Research Question

To what extent are the components and materials used to manufacture special test equipment obtained from foreign sources and what are the implications of reliance upon foreign sources?

2. Secondary Research Questions

- What are the STE components and materials?
- What components and materials are obtained exclusively from foreign sources, or, in addition to domestic sources?
- What are the principal reasons components and materials are obtained from foreign sources?

D. SCOPE AND LIMITATIONS

Depending on the application, the term "special test equipment" can have many meanings. For the purposes of this research, special test equipment will be limited to that test equipment which is used solely in the production process. To further reduce the field to a manageable level, given the constraints of time and resources, this research was restricted to special test equipment used by a single prime contractor in the production of missiles. The production STE of Texas Instruments' HARM missile program provided the foundation for this study.

There are two limiting factors one must consider when evaluating the data developed in this study. First, no STE units were reduced to their component parts, i.e., disassembled. The materials and components that were analyzed

were those used to support continuing operations. Continuing operations were those actions required to maintain and/or modify existing equipment. It is the researcher's opinion that the requirements of continuing operations and those of initial construction will be reasonably similar for determining the country of origin of the components in general. That opinion is supported by the STE Engineering Supervisor of the HARM missile program.

A second limitation was the depth and breadth of research possible with the limited resources available. Had more time, funding, and personnel been available, a more statistically significant analysis would have been developed. Preferably, more components and suppliers would have been examined, and ultimately subassemblies would have been examined in greater detail.

E. METHODOLOGY AND LITERATURE REVIEW

A detailed accounting of the evolution and final research methodology is presented in Chapter IV. An overview of the research methodology follows.

Concurrent with the decision to investigate the extent and implications of foreign sourced materials in manufacturing production STE, the determination was made to use missile programs for the case study. Several missile program offices were contacted within Naval Air Systems Command. Of those solicited, each granted their approval to pursue this study in

their program area. The program offices then provided points of contact in the government offices co-located at a prime contractor's facilities. In turn, the government representatives provided access tc the contractor's production STE personnel. The enormity of the size and scope of the research was soon realized. This led to a series of downsizing decisions. One program and manufacturer were ultimately selected--the HARM missile program and Texas Instruments, Inc.

An initial site visit was utilized to gain familiarity with the missile program, production STE and to finalize a procedure to conduct the study. Sizeable cost and personnel requirements, beyond the resources available, would have been required to break out STE to the piece-part level.

As a result, the data used to determine what materials and components were foreign sourced were limited to material usage data from continuing operations. Continuing operations are those actions required to maintain and/or modify existing equipment. The raw data were available in part due to requirements pertaining to government funded programs. The data included Texas Instruments' part numbers, manufacturer's part numbers and supplier names. A second list, with supplier's telephone numbers and points of contact, was prepared from the files of a manufacturing assistant.

With this information, the suppliers were contacted and their assistance requested in determining the nomenclature of

the part numbers and their place of origin. Several suppliers, particularly the actual manufacturers, were able to provide that information over the telephone. Others, primarily distributors, requested that copies of the raw data be telecopied to them for further research. Of these, approximately one-half responded with all or most of the requested information. Follow-on telephone calls were made to clarify any ambiguities in the responses. Finally, the data were segregated to be evaluated with regard to the research questions.

In addition to a physical determination of components and their origin, the professional opinions of industry representatives were also obtained. These individuals were all directly involved in production STE, the electronics industry, or both. As a final source, information was gathered from existing literature. For this study, existing literature turned out to be of minimum value.

Research questions were addressed and conclusions drawn based on analysis of the previously stated production STE data, professional opinions of industry representatives and existing literature. Since data from only part of one manufacture's STE were used, the results are not statistically conclusive. It is the opinion of the researcher, however, that they support an implication regarding foreign sourced materials and production STE.

F. ORGANIZATION OF THE STUDY

Chapter II presents the reader with a review of the existing literature and provides a general background of industrial base issues with an emphasis on foreign sourcing concerns. Chapter III provides an overview of special test equipment and government property, and how they are managed with government contracts. Chapter IV is an in-depth description of how the research methodology evolved. Chapter V is a presentation and analysis of the data as derived from the HARM missile production site. Finally, Chapter VI provides answers to the research questions, a summary and suggestions for further study.

II. BACKGROUND and LITERATURE REVIEW

A. INTRODUCTION

Reliance on foreign sourced materials, technology and capital equipment within the United States is more than a question of unemployed American workers and corporate profits remaining with overseas firms. Many U.S. companies, particularly lower-tier manufacturers, are closing their doors. Foreign sourcing is now an industrial base issue that deals with potential dependence on, and vulnerability to, non-domestic suppliers. While these issues have been addressed in the past, recent years have seen a resurgence in concern over the capabilities of our nation's industries. Certainly there are opposing views, but many feel that U.S. industries are losing or have already lost their dominance and competitive positions in a global economic society. The strength of America's industrial base is fundamental to continued growth of the nation's economy, its military and economic security, and to sustaining the quality of life most U.S. citizens have come to expect and enjoy.

The defense industrial base (DIB) is an important segment of the nation's industrial base. The defense industrial base is characterized as those products, materials and manufacturing capabilities essential to meet not only peacetime military requirements, but also surge and

mobilization requirements. A subfunction of the nation's industrial base, the requirements for a strong defense industrial base are generally the same. To meet its requirements, the DIB requires resources such as skilled labor, advanced production processes and engineering talents similar to those throughout all of industry.

B. CONCERNS FOR THE INDUSTRIAL BASE

The health of America's industrial base, including its reliance on foreign sourced materials, is not a new issue. To varying degrees, the concerns of foreign dependence, vulnerability and erosion of U.S. capabilities have been addressed since the earliest days of the nation. In his "Report on Manufactures" sent to the Speaker of the House of Representatives on December 5, 1791, Alexander Hamilton wrote:

> The Secretary of the Treasury in obedience to the order of ye House of Representatives, of the 15th day of January 1790, has applied his attention, at as early a period as his other duties would permit, to the subject of Manufactures; and particularly to the means of promoting such as will tend to render the United States, independent on foreign nations, for military and other essential supplies.

Throughout the years of the industrial revolution, the United States entered a unique balance between the opposing philosophies of international mercantilism and isolationism. Maintaining political distance from much of the world, the U.S. was at the same time expanding and developing foreign interests for economic purposes. The growing domestic industry was essentially self-sustaining. Less expensive

materials and labor abroad were instrumental in creating profitable ventures, but the use of foreign sourced materials was not in itself critical to American industry.

America's involvement in the Second World War renewed concerns of foreign dependence as well as surge and mobilization capabilities. Following the war, the National Security and Defense Production Acts of 1948 provided official recognition of U.S. dependence on imported minerals and raw materials. These legislative actions paved the way for the stockpiling of critical materials and the creation of standby allocations to safeguard sources of supply against future national emergencies, such as another war. [Ref. 2:p. 1] As defined in the Strategic and Critical Materials Stockpiling Act (1946), strategic and critical materials are those materials that:

1. would be needed to supply the military, industrial and essential civilian needs of the United States during a national emergency, and

2. are not found or produced in the United States in sufficient quantities to meet such need.

However, the economic prosperity of the times did not encourage a close or lasting scrutiny of foreign sourced material issues.

Emerging from World War II as the world's undisputed leader in manufacturing capability, the U.S. had no industrial or financial competition. An item produced in the United States would be readily accepted in any market. Through the

1950's and into the 1960's the U.S. remained the world's industrial powerhouse. It was not until the mid-1960's that some would again begin addressing the issue of foreign dependence. However, beyond the Department of Defense, several think tanks and a few industry executives, foreign sourcing was not an issue of importance.

The oil embargo of 1973 was the first time the average citizen was able to truly identify with the potential impact of foreign dependence. The frustrations of the moment raised cries for more fuel efficient products and the development of alternative fuels. Most importantly, it awakened America to one aspect of a dependence on a foreign sourced good. Unfortunately, even when there are wide-spread hardships and frustrations resulting from events such as the oil embargo, there is a short memory once these crises pass. There will always be a new "crisis" to fill the void and redirect energies. In attempting to rationalize the lack of public understanding and awareness in areas equally important but less visible then oil, former Congressman James D. Santini stated, "You don't buy cans of cobalt off the grocery shelf." [Ref. 2:p. 2]

Throughout the 1970's and 1980's the DoD, Congress and several Presidential Administrations initiated policies to continue identifying and stockpiling items that were not only critical to the industrial base, but essential to military objectives. Going a step further, the most recent legislation

requires the DoD to expand its planning to incorporate an "Industrial Preparedness Plan." The ultimate purpose of industrial preparedness planning is to provide adequate capabilities, both in materials and manufacturing capacity, to meet peacetime as well as surge and mobilization requirements. [Ref. 3]

The past several years have not only seen government officials and industry leaders, but now the general populace as well, beginning to recognize the potential dangers of increased foreign dependence. An emerging concern gaining acceptance is that the United States is losing its technological advantages in conjunction with increasing dependence on foreign materials. It is the opinion of many that the United States has not only lost its dominant position, but is actually falling behind other industrialized nations. As this concern develops, the country is simultaneously seeing an unprecedented increase of imported goods. These are imported goods that are no longer relegated to items such as exotic metals mined only in other countries. Now imports also include automobiles, electronics equipment and machine tools. In many instances they are displacing U.S. producers in domestic markets.

C. DOMESTIC CAPABILITIES

Although slightly dated, results of a 1984 survey by Purchasing magazine are unsettling. Questioning U.S.

companies on their use of foreign sourced materials, 62 percent of the respondents indicated that they would maintain the same level of imported goods they had the previous year. An additional 27 percent said they would increase their use of foreign sourced materials. Only 11 percent said they intended to use fewer foreign sourced items. [Ref. 4]

Unfortunately, the survey results were not segregated by industry and specific types of purchases. This would have presented a more accurate picture of the distribution of the use of foreign materials by industry. In general, the types of materials obtained by the survey respondents covered an extremely broad spectrum. These materials included steel, machine tools, fasteners, valves, repair parts, chemicals, electronic components, decorative ornaments and paper-backed wall coverings.

The respondents rated their foreign and domestic suppliers in the following manner:

Category	Respondents rating domestic suppliers best	Respondents rating foreign suppliers best
Price	12%	88%
Quality	37%	63%
Availability	56%	44%
Responsiveness	59%	41%
Technical assistance	64%	36%

Obviously most companies will weigh a variety of factors before choosing their vendors. But, in a highly competitive environment, price and quality are generally considered

crucial to maintaining a competitive position. The survey respondents rated foreign suppliers favorably in both of these categories. The foreign suppliers were rated poorly in responsiveness and technical assistance. Week performance in these areas is often a result of geographical separations. As communications technologies continue to advance, there is the possibility that off shore suppliers will increase their competitive position in these categories also.

A two-year study by the Massachusetts Institute of Technology, released in 1989, confirmed that U.S. productivity in major industrial sectors was declining. [Ref. 5] This study was based solely on the productivity of eight key U.S. industries. It did not address the impact of events such as trade deficits and global economic changes. The eight industries examined were commercial aircraft, consumer electronics, computers and semiconductors, machine tools, chemicals, automobiles, steel and textiles. These industries account for approximately 28 percent of this country's manufacturing. They are also responsible for approximately one-half of all U.S. imports and exports of manufactured goods.

Examples of situations where the U.S. has lost a dominate position in a market over the last 20 years abound. They include the auto industry, machine tools and consumer electronics. One of the most recent shifts in dominance is in the semiconductor industry. Today these components are

critical to untold thousands of products throughout the world. Additionally, their use and sophistication is continuously expanding. Domestic electronics products tied to the semiconductor industry provide approximately 2.6 million jobs for U.S. workers. [Ref. 6]

In 1980 the U.S. dominated the semiconductor industry, providing 61 percent of the world's sales. By 1985 the U.S. had dropped to 44 percent and Japan had risen to 44 percent of world sales. In 1989 Japanese sales of semiconductors outperformed U.S. sales by 12 percent. Revenues from semiconductor sales tripled in the U.S. between 1982 and 1988. In Japan, revenues had risen sixfold over that same period. [Ref. 6]

In the domestic market, U.S. semiconductor manufacturers' share of the market has been reduced to approximately 70 percent while Japanese semiconductors have increased in market share from five to approximately 30 percent. In Japan, U.S. manufacturers have maintained only a ten percent share of the semiconductor market over the past ten years. [Ref. 6]

A particular concern is that foreign sourced items may become vulnerable items, i.e., an item that is provided by a foreign source only with no alternatives available should trade be inhibited. There are two ways for this to happen. First, the raw materials are not available within the U.S.; second, U.S. technological advances do not keep pace with other nations. One example of this vulnerability was when

researchers at Bell Labs had to wait one year for delivery of a laser diode from Hitachi. The diode was a critical component in an optical computer research program. [Ref. 7]

Sony Chairman Akio Morita and former Japanese minister Shintaro Ishihara believe that the Japanese have such advanced production skills and sophisticated semiconductors that the U.S. could become almost totally dependent on Japan. They argue that if the supply of advanced semiconductors to the U.S. were cut off, and redirected to the Soviet Union, Japan could reshape the balance of power. [Ref. 6]

The semiconductor industry is divided into two general segments: semiconductor manufacturing, and the supply of equipment and materials. One of only two U.S. firms capable of providing semiconductor manufacturing equipment, Perkin-Elmer Corporation, had been unable to find a U.S. buyer for its optical lithograph equipment. Optical lithography is a critical process in the manufacture of semiconductors. When the possible acquisition of Perkin-Elmer's highly sophisticated unit by a Japanese firm surfaced, it caused concern through both industry and DoD. [Ref. 8]

A final view of these trends is reflected in the U.S. trade deficit. A somewhat positive reflection, the trade deficit in low technology manufactured goods was narrowed by $44 billion between 1986 and 1989. But countering this was a shrinking trade surplus in high technology manufactured goods. Between 1986 and 1989 this surplus grew by only $11.7 billion.

As reported by the Commerce Department, the nation's "advanced technology" trade surplus declined by $2.5 billion in 1989. [Ref. 9]

D. DEFENSE INDUSTRIAL BASE

The Defense Industrial Base (DIB) is a reflection of the nation's industrial base. The technology, production processes and sources of materials important to the DIB are much the same as those important to the nation's industrial base.

Aggravating the situation of the DIB, many firms refuse to accept or are divesting themselves of government, and particularly DoD business. According to a study by the Center for Strategic and International Studies, of 118,000 firms that provided goods to the DoD in 1982, 80,000 had either closed or turned exclusively to the civilian community by 1987. [Ref. 10] These figures are particularly discouraging when considering the high defense spending of the period.

Many reasons are given by companies for turning away defense work. Some of the major reasons include excessive paper work, poor and overly restrictive specifications, excessive oversight and program instability.

Burdensome paper work was cited by 70 percent of the respondents in a 1988 survey as one of the leading causes of problems when dealing with the government. When firms sell to the government, administration costs are significantly

greater than when dealing with commercial enterprises. These costs result from special office arrangements and personnel specially trained in government procedures, multiple forms, excessive documentation and inconsistencies between specifications and statements of work. [Ref. 11]

Excessive oversight is a continuous and well-documented point of contention. Private industry commits extensive resources to preparing numerous reports and supporting a variety of audits. As an example of the situation at one production facility, for every General Electric engineer on a military jet engine production line, there is a DoD inspector and auditor. By contrast, no one from the commercial airline or airframe industry monitors the commercial jet engine production line. [Ref. 10] To ensure honesty among the contractors, the government employs 26,000 auditors. Not only does this create non-value added inspections which increase costs, it creates the impression that the entire defense industry is inefficient and dishonest. [Ref. 5]

Impacting the lower tier subcontractors, as well as the prime contractors, is program instability. For example, the original Army request for the AH-64 helicopter was 1300 aircraft. It changed to 575, then 1200, and most recently 840. Allied-Signal invested $106 million of its research funds in the development of the F-109 engine to be used in a new Air Force trainer. The entire program was cancelled. [Ref. 12] Inherent destabilizing factors of the current

defense acquisition process are annual appropriations and dynamic political situations. These are exaggerated by unrealistic and over optimistic projections of both quantities and prices, by both industry and DoD.

Companies are not reinvesting in capital equipment, which is producing a long range impact on the DIB, and to some extent the nation's industrial base. Failure to reinvest will prohibit industries from maintaining competitive advantages in advanced technologies and production processes. Additionally, because companies that do not reinvest in capital equipment will have depreciated their equipment, those that do reinvest may not be able to successfully compete in price competition. In recent years price competition has dominated government procurement.

In a 1988 report to the Secretary of Defense by the Under Secretary of Defense (Acquisition), the following was noted: [Ref. 13:p. 25]

- Critical defense industries did no worse than overall manufacturers in maintaining a domestic market share in the face of substantial import growth;

- Critical defense industries did worse than overall manufacturers in terms of adding to productive capacity, with only 41 percent of critical defense industries matching or exceeding the overall manufacturing average growth in productive capacity;

- Three-quarters of critical defense industries achieved worse than average growth in real shipments;

- Sixty-two percent of critical defense industries had lower than average capital expenditures in 1980. This adverse trend continued in 1985, when 72 percent had lower than average capital expenditures;

- Forty-seven percent of critical defense industries had below average productivity growth (17 actually had declining productivity);

- Critical defense industries achieved average or above average profitability.

In response to a request in the National Defense Authorization Act for Fiscal Year 1989, DoD provided Congress with a list of technologies that they determined to be critical to defense. The Pentagon highlighted 22 technologies "with great promise of ensuring the long-term superiority of United States weapons systems." [Ref. 14] The technologies deemed critical by DoD are not exclusively focused on pure or direct military applications. They include technologies that will determine the future health and global competitiveness of the nation's industries. Among the 22 technologies were microelectronics circuits and their fabrication, preparation of gallium arsenide and other compound semi-conductors, software producibility, machine intelligence and robotics, fiber optics, and biotechnology materials and processing.

Many of the DIB concerns lie with the health of the lower tier subcontractors. Over 70 percent of the companies that make up the DIB are classified as subcontractors. Since the end of the Viet Nam War, thousands of firms in this category have dropped out of the defense business and others are reluctant to expand. [Ref. 15:p. 2.5] In the event of a surge or mobilization, it is in the lower tiers that bottle-necks are expected. Even though primes are expected to have

the required capacity, the subcontractors will not have sufficient capacity to meet the demands of those primes competing for limited resources.

An example of the potential impact of the loss of a lower tier supplier occurred in 1989, when NASA and the DoD lost their only qualified supplier of rayon fiber. Continuous filament, carbonizable rayon yarn is used in a variety of products. These include shuttle booster motors, intercontinental missiles, and tactical missiles such as the Stinger. The Avtex Fibers Co., a fifth level subcontractor, closed its doors after a year long battle over environmental issues. In this case NASA and DoD were able to approve emergency funding and have Avtex opened long enough to produce materials to stockpile. The next permanent source is not expected to be qualified until May, 1991. [Ref. 16]

There is general agreement that most technological breakthroughs occur at the subcontractor level. The subcontractors are the experts in their field and innovation is often the key to their survival. As the lower tiers shrink in numbers, there will be less competition, subsystem research and development will suffer, and entrepreneurship will diminish. [Ref. 17] The final result will be a less responsive and capable DIB. Clearly, the well-being of lower tier subcontractors is essential to avoiding dramatic, negative impacts on the capabilities of prime contractors.

E. HEALTHY ASPECTS OF THE INDUSTRIAL BASE

There is no escaping the fact that Japan, with an economy half the size of the U.S., took the lead in technology intensive exports in 1986. Or, that in 1989, Japan exceeded U.S. investments in industrial plants and equipment by nine percent. [Ref. 18] Currently the U.S. has almost half of the world's technical Ph.D's. But, as education levels rise throughout the world, that advantage will erode. Still, the health of the nation's industry is not such that the country is necessarily destined to a position of international inferiority.

The U.S. has the highest manufacturing productivity in the world, and is still the world's greatest exporter. Unemployment has been steady at between five and six percent and exports have been steady at approximately 22 percent of GNP. [Ref. 19] Despite unfavorable balances between high and low technology exports, U.S. exports are increasing.

The U.S., both industry and government, spends $15 billion a year on basic research, more than any other country. Within the U.S. there are 15 million companies engaged in almost every discipline known to man. American companies and laboratories led the way in reproducing millions of copies of a DNA strand, advancing plastics and composite materials, and developing high speed computers and components. In the semiconductor industry, IBM brought out the world's first 4 megabit memory chip. [Ref. 19]

Corporations within the U.S. hold patents on and produce the world's best fiber optic cables. At AT&T, research is under way to develop an optical computer. Dr. Alan Huang, head of the optical research department at Bell Labs, believes a simple optical computer can be assembled before 1995. A member of Dr. Huang's team, David Miller, developed the first photonic switching chip, the Self Electro-optic Effect Device (SEED). [Ref. 7]

The impact of government spending, particularly defense spending, on the nation's industrial base has been substantial. Two of the nation's strongest industries, aerospace and telecommunications, are direct results of government spending. The household micro wave is the result of accelerated defense research during World War II.

But not everyone believes defense spending is the best method to project America's industry ahead. Corporate executives interviewed for a report by the Bulletin of the Atomic Scientists, saw the Defense Department as a sponsor of technologies that have little commercial relevance. They said that defense contractors exist in a kind of "ghetto," working with technologies and business practices that actually hinder them from competing in the commercial market place. [Ref. 20]

Government and DoD procurement rules are such that corporations that supply similar items to both private industry and the defense industry are forced to establish separate divisions for each. The results are often lower

quantities in the defense division and higher overhead costs. The result is that DoD pays considerably more for an identical or similar item than private industry.

Another issue concerns the resources consumed by DoD on research. Up to half of the research and development (R&D) in this country is defense related. The money spent on defense R&D detracts from that which firms could otherwise use to pursue R&D with commercial applications. Additionally, many of the nation's most skilled scientists and engineers are hired away from commercial practices. [Ref. 20]

Others see DoD's Defense Advanced Research Projects Agency (DARPA) as America's answer to Japan's Ministry of International Trade and Industry (MITI). MITI, which targets about $1 billion annually at selected R&D areas, is widely credited with Japan's postwar economic recovery and international preeminence. [Ref. 21] Despite problems associated with government spending discussed earlier, these individuals believe DoD is the only organization powerful enough to do for the U.S. what MITI did for Japan.

Although DoD is not a large enough customer to sustain an industry, the capabilities of many industries are a concern of DoD. When the machine tool industry went into a steep decline, the Defense Department provided $15 million to the National Center for Manufacturing Sciences. Other industries targeted for DoD assistance are advanced synthetic materials and the manufacturing of ball bearings. [Ref. 20]

In conjunction with the Defense Science Board (DSB), DARPA provides R&D defense dollars for dual-use, or technologies with military and commercial applications. Current programs of DARPA include $30 million to companies interested in developing high-definition television (HDTV), $25 million for research in superconductivity, and $4 million to a small Silicon Valley manufacturer to aid in developing a faster gallium arsenide computer chip. [Ref. 22]

A joint venture between private industry and DoD, the Semiconductor Manufacturing Technology Institute (SEMATECH) pursues research for the purpose of "providing important commercial advantages to U.S. semiconductor manufacturers by developing and transferring advanced manufacturing technologies." [Ref. 23] A non-profit consortium of 14 electronics companies, SEMATECH, was formed in August 1987. Since it was authorized by Congress in December 1987, SEMATECH has received $100 million annually from DoD. This represents approximately half of SEMATECH's budget. The member companies contribute the remaining funds.

The health and vitality of the nation's industrial base is a critical element in the equation that determines the nation's health and prosperity. Within the nation's industrial base, the DIB reflects the same general strengths and weaknesses. To ensure economic competitiveness in a global market, and ultimately the security of the nation, it is essential that continued focus be given to such areas as

education, new technology and process R&D, productivity, and foreign sourcing.

In the study performed by this researcher, an attempt was made to determine the extent to which foreign sourced components were used in U.S. production special test equipment. The following chapter provides the reader with an understanding of what production STE is and how it is managed as government property in conjunction with a government contract.

III. GOVERNMENT CONTRACTING AND GOVERNMENT PROPERTY

A. INTRODUCTION

The purpose of this study is to determine the extent and implications of foreign sourced materials used in the manufacturing of production special test equipment (STE). The intent of this chapter is to provide the reader with an understanding of what STE is, how it is used and the administrative requirements that apply when STE is used to perform a government contract.

In government contracting it is not uncommon for materials, equipment or property to be furnished to the contractor by the government. These items are referred to and categorized as "GFM, GFE, and GFP." Government furnished materials (GFM) are normally consumable items. An example would be a bar stock furnished by the government for a specific purpose. During the production process that bar stock will be reshaped, cut and machined to become part of the final product.

An example of government furnished equipment (GFE) can be illustrated with a military aircraft procurement. The prime contractor is often referred to as a systems integrator. As such, the prime does not build the entire aircraft in-house. In many cases as much as 50 percent of the procurement is subcontracted to other companies. However, not all of the subsystems and components are subcontracted. Different

subsystems, such as engines and fire control systems, are frequently provided by the government. The government contracts with individual companies for these subsystems and then provides them to the aircraft manufacturer as GFE. The prime contractor will then assemble the contractor procured equipment and materials, and GFE, to produce the final product.

The government may also furnish the contractor with facilities, plant equipment, special tooling and special test equipment. This is referred to as government furnished property (GFP). Government property is all property "owned by or leased to the government or acquired by the government under terms of the contract. It includes both government furnished property and contractor acquired property." [Ref. 24:Sec. 45.101] As used here, contractor acquired property is that property which, under contract, the contractor procures and for which he is reimbursed. The government retains title of the property.

It is the written policy of the government that contractors will ordinarily be required to furnish all property needed to preform government contracts. Despite this policy, contractors often use government property. When contractors do possess government property, the government agencies controlling that property are required to pursue the following: [Ref. 24:Sec. 45.102]

1. Eliminate to the maximum practical extent any competitive advantage that might arise from using such property.

2. Require contractors to use government property to the maximum practical extent in performing government contracts.

3. Permit the property to be used only when authorized.

4. Charge appropriate rentals when the property is authorized for use on other than a rent-free basis.

5. Require contractors to be responsible and accountable for keeping the government's official records of government property in their possession or control.

6. Require contractors to review and provide justification for retaining government property not currently in use.

7. Ensure maximum practical reutilization of contractor inventory within the government.

GFP was used sparingly by contractors prior to the Second World War. However, the mobilization requirements of that war brought about an extensive use of government supplied property. At the time the nation had limited industrial capabilities, limited capital available for expansion, a resistance to work with the government, and a belief that the war would not last long enough to allow businesses to recover from their capital investment expenses. [Ref. 25:p. 5] Strong government intervention was required to assist and spur industry to the production levels that would see the U.S. through the war. To a large extent those early government actions influenced today's government property and government/contractor relationships. While the priorities may have shifted since World War II, much of the same rational remains today for the utilization of government property.

There are many instances when it is to the government's advantage to furnish GFP. Broken out by purpose, several examples are provided below. [Ref. 26:p. 31]

1. Type of contract. On a cost reimbursement type of contract, all assets acquired or produced that are paid for by the government are, by definition, government owned property.

2. Economy. A major reason for furnishing property to contractors is to obtain a favorable price. The cost may be reduced if the contractor does not have to acquire or build certain types of assets that the government already owns.

3. Standardization. When several contractors are working on a similar project or production item, it may be desirable for the government to furnish equipment or materials in order to assure uniformity in the end product.

4. Security. Sometimes, performance of the contract requires the use of classified items, (top secret, secret, confidential) that can only be provided to the contractor by the government.

5. Increased Competition. In those situations where only a limited number of contractors are interested in responding to a government solicitation because of the expensive tooling or exotic machinery required, GFP may increase the number of potential bidders by removing some of the main handicaps to their participation. In some cases, GFP may contribute to breaking out of a sole-source situation.

6. Support of Small Business. A small business may have the labor, skills, and the source materials that are required to perform certain types of government contracts, but may not be able to afford the investment in certain expensive or unique items of equipment. Government furnished equipment can be used in such instances to support the DoD policy of aid to small business.

7. To Expedite Production. Many tools, equipment, and materials require long lead times to produce or acquire. If the government can make such items available from existing stocks, the lead time for end item production may be substantially reduced.

8. Scarcity of Assets. Some types of items required for performance of government are of such critical nature and in

such a limited supply that only the government can guarantee availability of the required quantity at the required time.

9. To Maintain the Industrial Base. Experience in several major wars has taught us that certain types and quantities of industrial equipment and tooling must be available at all times in order to provide a base for rapid production of essential military items. Private industry is neither willing nor able to maintain the investment in equipment required for this purpose. As a result, government owned assets are used to supplement the industrial capability of the civilian economy.

B. SPECIAL TEST EQUIPMENT

The focus of this study is foreign sourced materials used in production STE. There is no specific type of equipment that must be labeled STE. STE serves a multitude of purposes and is as diverse as the processes and products of industry. For purposes of government contracting, STE is defined as follows: [Ref. 24:Sec. 45.101]

> Special test equipment means either single or multi-purpose integrated test units engineered, designed, fabricated, or modified to accomplish special purpose testing in performing a contract. It consists of items or assemblies of equipment including standard or general purpose items or components that are interconnected and interdependent so as to become a new functional entity for special testing purposes. It does not include material, special tooling, facilities (except foundations and similar improvements necessary for installing special test equipment), and plant equipment items used for general plant testing purposes.

The STE evaluated in this study was that used by Texas Instruments at their HARM missile production site located in Lewisville, Texas. Meeting the criteria of the definition above, that STE was designed and built solely to support the unique requirements of that production program. To avoid

confusion, it should be noted that the term STE may be used to represent one or many pieces of equipment. In the case of the Texas Instruments HARM missile program, over 130 different pieces of equipment were designed and built by that company and designated as STE. Texas Instruments was reimbursed for the associated costs, and the government retained title.

These pieces of test equipment perform a variety of tests and diagnostics throughout the production process. One example may serve to clarify the use of STE. At the lowest level of testing, components on a printed wiring board are tested to insure that they perform the intended function of that component. The resistors, transistors and integrated circuits are each checked by a piece of STE to insure they are functioning as designed.

At the next level of testing, with different STE, the same printed wiring board is tested to ensure it functions properly as a subassembly. This insures that all of the components are performing together as desired. An example would be to test an amplifier and feedback loop to insure that it does in fact amplify a signal as planned, and is able to self-correct with certain feedback.

A third level of testing involves a higher level subassembly made up of several printed wiring boards. These printed wiring boards have each been individually tested at least twice previously. Then they are tested to insure that they function together in a higher integrated subassembly.

A final test would be conducted on the completed assembly. The final assembly is tested and evaluated to insure that it is capable of performing the function for which it was designed. In this situation individual components will have been tested at least four times.

There are no unique criteria for testing components, subassemblies and final units. Required tests will be determined in conjunction with the system design requirements. Just as STE is different for each application, each production process will have its own testing requirements. STE will be built and configured to those needs.

Often STE is unique and is neither commercially available nor furnished by the government. One of the methods for a contractor to obtain GFP in such circumstances is to design and build it themselves. Texas Instruments did this with most of its HARM missile STE. Having designed the missile system to be manufactured, they were the most qualified to design the STE. The STE design first had to be approved by the government. Texas Instruments then built the equipment that was to be used to test their products throughout production. Due to contract agreements, the government retains title to the STE. If Texas Instruments later determines that a modification is required, they must first get government agreement, and then incorporate the modification. The government may also initiate a modification to the contract to change or expand test requirements.

One exception to this tight control is when the contractor uses its own financial resources to acquire or produce STE. This is done when the contractor desires to retain title of the equipment. This is likely to occur in situations involving equipment with a specific function that will be usable on other products or non-government contracts at a later date.

This is illustrated by environmental chambers that Texas Instruments maintains as capital equipment. The environmental chambers dedicated to the HARM missile program are capable of varying inside temperatures from approximately minus 45 degrees Celsius to plus 71 degrees Celsius. The purpose of these chambers is to test the operation of subassemblies and assemblies through a series of extreme temperature changes. The environmental chambers are considered STE but are not unique to producing HARM missiles, i.e., they may be used for the testing of other systems. It is likely that Texas Instruments will have additional future use for them that may or may not be associated with a government contract.

C. PROPERTY ADMINISTRATION

The management of government property used by contractors is a function of contract administration and is typically under the auspices of the Administrative Contracting Officer and a Property Administrator. It is also a joint responsibility of both the government and contractor.

When applicable, it is the government's responsibility to insure that government property, in accordance with the contract, is delivered to the contractor in a timely fashion and in the condition both parties had agreed upon. Failure of the government to do so may provide the contractor with legitimate grounds to delay delivery.

Once the contractor has custody of government property, whether delivered by the government or procured by the contractor, the contractor is responsible for maintaining that property. Levels of responsibility vary, depending on how the contract is written.

Generally, when the contract is a firm fixed price (FFP) contract, the contractor assumes total responsibility for the property. If the contract is a cost reimbursement type contract, the government assumes greater responsibility and essentially self-insures. [Ref. 24:Sec. 45.103] With either type of contract, the contractor is required to perform normal maintenance and upkeep, and will not be held liable for normal wear. As custodian, the contractor is also required to maintain any applicable government records and logbooks for that equipment. Finally, it is the contractor's responsibility to maintain a government approved method of inventory and accountability.

Regardless of the contract type, the government's role is one of oversight and equipment utilization management. Oversight includes approving the contractor's property control

system, making recommendations if disapproved, and performing audits and inspections to insure compliance.

Proper equipment utilization includes the efficient use of government property from its acquisition through disposal. If, in response to a solicitation, the contractor indicates that it is necessary to acquire or fabricate STE, it is the contracting officer's responsibility to: [Ref. 24:Sec. 45.307]

1. Review the proposed items for necessity and proper classification as "special" test equipment;

2. Screen the availability of existing government owned test equipment in accordance with agency procedures; and

3. Notify the contractor, approving or disapproving the acquisition or fabrication and, if it is disapproved, state whether the equipment will be furnished by the government.

The screening for availability of existing equipment is done through the Defense Industrial Plant Equipment Center (DIPEC), at Memphis, Tennessee. Most STE, because of its dollar value, will be classified as industrial equipment. DIPEC is charged with managing all DoD industrial equipment. Prior to a contracting officer approving new STE, a statement of non-availability must be obtained from DIPEC. [Ref. 26:p. 36]

Once a contract is completed, or if GFP (to include STE) becomes excess, there are extensive procedures to be followed by the government. In general, and in priority as listed, the Contracting Officer will: [Ref 24:Sec. 45.603]

1. Encourage the purchase of the property, at cost, by the contractor.

2. Redistribute the property throughout the government.

3. Donate the property to eligible causes.

4. Sell the property to parties other than the contractor having custody.

5. Donate the property to public bodies.

6. Abandon or destroy the property.

Requirements, methods and procedures used to determine eligibility when disposing of excess property are a function of the Federal Acquisition Regulation, Agency regulations, General Services Administration procedures and the procedures of the Defense Property Disposal Service (DPDS).

As presented, government property, which includes STE, is a unique area of contract requirements and administration. To determine the extent of foreign sourced components in production STE, the following chapter presents a detailed explanation of the research methodology and its evolution.

IV. RESEARCH METHODOLOGY

A. INTRODUCTION

The intent of this research is to examine the extent and possible impact of foreign sourcing on a segment of the U.S. industrial base. Test equipment, and the source of components within test equipment, was selected to be the industrial base segment studied. An informal study performed earlier by another researcher had suggested that as much as 30 percent of component parts that make up test equipment used in this country is manufactured overseas. [Ref. 1] To narrow the scope of this study, the determination was made to explore the extent to which foreign sourced components were used in special test equipment (STE).

STE was limited to that equipment used only in the production manufacturing process. This is STE that is not expected to be used in the field by government operating units or their various levels of maintenance support. Typically, this test equipment is unique to a specific manufacturer and product line. It has been designed and manufactured by the contractor to perform tests, take measurements and run diagnostics on the subassemblies and final assemblies that are produced at a single location. While not intended as part of this study, some of the production STE eventually evaluated was used by the manufacturer to perform both depot level

maintenance functions and production functions. The manufacturer's depot level maintenance function was an interim measure that will not be required as the government acquires organic capabilities.

The research evolved into two distinct elements. First, a search and review of literature that may have already been compiled in this area; and second, a limited physical examination of selected test equipment and its components.

B. LITERATURE REVIEW

The purpose of the literature review was to acquire knowledge of industrial base issues in general, to develop a better understanding of potential U.S. dependencies and vulnerabilities, and to examine any previous work that may have been done specifically within the scope of this research paper.

Initially, custom bibliographies were requested from the Defense Logistics Studies Information Exchange (DLSIE) and the Defense Technical Information Center (DTIC). Additional sources included the General Accounting Office (GAO), Naval Research Advisory Committee, Naval Postgraduate School, Dudley Knox library, as well as such professional organizations as the Society of Logistics Engineers (SOLE), Production Management Institute (PMI), and the Semiconductor Manufacturing Technology Institute (SEMATECH).

The effort provided substantial information concerning potential and established shortcomings within the U.S. industrial base as well as areas of strength. However, no documentation was discovered that addresses the issue of foreign sourced components used in test equipment, or the broad field of "test and measurement equipment."

In the course of coordinating the case study and searching for applicable literature, many people in private industry and professional associations were contacted. Representative industries and associations include Motorola Inc., UNISYS Corporation, Lockheed Missiles & Space Co. Inc., Society of Logistics Engineers and the Production Management Institute. Several of these are shown in the Bibliography. With considerable experience in electronics, test equipment, or both, these individuals offered their expert opinion on the extent of foreign sourced components within production STE. Although these individuals did not have conclusive proof of their suspicions, their professional judgments were analyzed and, when appropriate, conclusions made.

C. CASE STUDY

The original intent of this study was to examine the component parts of several pieces of similar production STE. Once identifying the individual component parts of which this equipment was comprised, these components would be evaluated in relation to the research questions.

The broad field of production STE was further narrowed to that equipment used in the support of government missile programs. A government program was selected for two reasons. One, the government programs are more closely aligned with this researcher's background, current studies and future career possibilities than a non-government program. Secondly, a government program was more accessible and the research charter carried the endorsement of the government program management office.

The selection of production missile systems was based on several factors. First, it was felt that a missile system was something that could more easily be bounded than a weapons system such as an aircraft or armored vehicle. These larger weapons systems are comprised of a significant number of subsystems, any of which could support a separate research paper. It was also felt that working with a number of subsystems would provide too much diversity when trying to look at similar types of production STE used throughout several programs.

Another concern was that subsystems produced by different subcontractors might present many management layers between the government program office and the management of the subsystem. This would cause additional coordination efforts. Also, since a missile system is a relatively small system, more than one program could be studied. To provide a data base of adequate size to make comparisons and draw conclusions

with confidence, examination of three to five missile programs was anticipated.

Only prime contractors' systems would be reviewed. It was felt that management support at this level would be more closely aligned with the government program office. Also, unlike an aircraft manufacturer who is in many ways an assembler and integrator, the missile manufacturers appeared to be more closely involved with both the design and the production of the entire product. Reduced comparative size and complexity of a missile system permits the contractor to be closer to the product. The significant perceived advantage was that the prime contractor was not only close to the product, but production facilities were much more contained.

An early key to this research was to select potential missile programs, gain support of the government program management office and acquire points of contact within the prime contractor's facilities. Because of the researcher's background in aircraft maintenance, air launched missile systems were selected to be the study models. The program offices of the Navy's air launched missiles are located within the Naval Air Systems Command (NAVAIR), Washington, DC.

After selecting air launched missiles, it was a matter of gaining access to each program manager, explaining the background, purpose and intent of the study, and receiving their approval to delve into this unique segment of their program. Each of the four program managers contacted was

willing to assist and allow this research to be conducted. The program offices provided both endorsements and points of contact within the contractor's facilities, or in the government plant representative offices.

After discussing the proposed study with several program managers, their field representatives and the appropriate personnel within the contractor's organizations, it became apparent that the scope of this research was still too broad. Each production site had the potential of providing upwards of hundreds of pieces of production STE. Even when narrowed to like equipment, the prospect of evaluating the source of the components within the equipment was unrealistic. It was decided to use only three contractors. Despite what would be a substantial effort on their part, companies representing three programs expressed a willingness to participate in the study.

The original programs selected were the HARM missile, the Maverick missile and the Tomahawk (cruise) missile. There were reservations with using the Tomahawk. The air launched version of the Tomahawk was never operational and the missile is considerably larger and more complex then either of the other two. The additional complexities and subsystems might make it difficult to draw comparisons between its production STE and that of the others. However, the geographical location of the production facility was the most favorable of

the three and would best lend itself to any travel requirements.

As the thesis proposal continued to be developed with the contractors, the enormity of the project continued to grow. As a result, it was decided to limit the research to two contractors and two missile systems. These were Texas Instruments with the HARM missile and General Dynamics Convair with the Tomahawk. Texas Instruments was selected because they had shown the most interest and enthusiasm in the project. Despite earlier reservations about the Tomahawk, General Dynamics was chosen because they were interested and provided the best geographical location should repeated visits become necessary.

After narrowing the field to two contractors, it was felt that a site visit to each would be beneficial. The most significant benefit was to give the researcher a better understanding of exactly what production STE is comprised of, how it is used, and how it is developed and assembled. Another strong case for the site visit was to meet face to face with those who would be providing time and resources to make this research possible. It was also hoped to better definitize the project's scope and research methodology with the benefit of corporate knowledge of the contractor's personnel. Two full days were scheduled with each contractor.

Prior to the site visits to the participating manufacturers, a visit of approximately two hours was

coordinated with Lockheed Missiles & Space Co. Inc., of Sunnyvale, California. A short commute for the researcher, the object of this visit was to begin to develop an understanding of the terminology and major systems of a missile, and the various types and applications of production STE used in producing a missile. This trip proved to be very beneficial in that it provided the researcher with a basic but useful understanding and appreciation of the overall production process of a missile system. It also provided further insight to the enormity of the research task that still lay ahead. Lockheed is the prime contractor of the Trident II inter-continental ballistic missile.

The initial plant visit as part of the actual study was with Texas Instruments and the HARM Missile program. It was learned that Texas Instruments has over 130 pieces of test equipment categorized as production STE and dedicated to the HARM missile program. Because of the sheer numbers, complexity and time constraints, it was decided to limit the study to only one manufacturer. This proved to be the only site visit as part of the study.

The original intent of the study was to look at several production programs. This would provide a more statistically valid sampling. However, from the very early phases of this study, it was evident that the sample size would have to be reduced. Again this was a factor of the size, complexity and time available to conduct the research.

A tour of the HARM missile production complex provided considerable insight to both the missile being produced and the manufacturing equipment involved in the process. While it was not a requirement to develop a sound understanding of the product, production process and support equipment, an elementary understanding of these elements aided in developing a better prospective of the types, functions and physical characteristics of production STE. This provided better insight to the entire research environment.

The next step in this process was to reduce a piece of the STE to its component parts. It was originally believed that it would be necessary to begin with equipment drawings and then work back to the individual components. Next, the components used would be physically identified. Finally, the components would be tracked throughout purchasing and on to the original suppliers and manufactures.

The personnel at Texas Instruments responsible for the design, manufacture and maintenance of the HARM missile program STE provided an alternative. Because all work and materials used must be charged to a specific project code, they were able to extract material usage information from their information system data base by project and fiscal year.

Extracting the material usage for production STE over several years provided a voluminous listing of raw data. This included five years of material used to manufacture, modify and maintain the STE. Again it was necessary to reduce the

breadth to a manageable proportion. It was not possible to pursue more than a fraction of the data provided.

The category chosen was the most recently completed fiscal year of continuing operations. This included all materials used by Texas Instruments to support the STE dedicated to the HARM missile program. Choosing continuing operations was an arbitrary decision. However, it was felt that components required after the initial assembly of the equipment, or of a repetitive nature, would be a more critical item in terms of requirements and availability then a component only used once, in the initial assembly.

The most recently completed project for continuing operations in which data were available was for the period November 1988 to October 1989. Using only this particular project, a computer generated usage list was developed. The data fields requested provided the Texas Instruments part number, original manufactures' part number, name of the supplier, purchase order number and project code. The software used was not able to provide a component nomenclature for the individual part numbers. These data for one year included approximately 1800 line items provided by approximately 260 suppliers.

Individual suppliers were to be contacted and asked to identify part numbers by nomenclature and indicate where that component was produced. The geographical location of the assembly site was requested in the case of assemblies.

At this point, as the first information was being obtained from suppliers, Texas Instruments was forced to reduce its active assistance. This was primarily due to internal work loads generated by operating at full capacity.

The loss of this valuable resource again forced a change in the scope of the research. The original intent was to follow as many of these components as possible, as far down the supply chain as possible. It was hoped that the country of manufacture could be determined in most instances, not only for piece parts, but also for many of the components making up the subassemblies.

With considerable raw data and limited resources it was decided to continue as best possible. Suppliers that provided the larger quantities of components to this project code were contacted first, working down to the suppliers who provided five or fewer components. Of approximately 260 suppliers associated with this project, 62 were contacted. Those 62 suppliers represented approximately three-fourths of the individual items or purchases over the one year period. Of those contacted, 39 suppliers eventually provided usable information.

Many of the suppliers, particularly those who provided few items, were able to provide sufficient information over the telephone on initial contact. This was particularly true when the supplier was the manufacturer, or when the supplier was a

distributor with a relationship to the manufacturer such that they were knowledgeable of the requested information.

Twenty-one suppliers had requested that the Texas Instruments data be telecopied to them for additional research. Along with the data, a brief letter was sent reiterating the nature of the study, its goals, and points of contact within Texas Instruments. The purpose of providing points of contact at Texas Instruments was to give suppliers sufficient information to verify the researcher's relationship to the company. Ten of these 21 suppliers responded with all or portions of the requested information.

As stated, time and resources did not allow all suppliers and components to be investigated. Many of the 260 suppliers were not contacted because the unit price of the material they provided was low. Typically these were inexpensive items with unit costs of less than one dollar.

D. DIFFICULTIES ENCOUNTERED

No unusual difficulties were encountered in searching for background information on industrial base issues. A considerable amount has been written on the erosion, or potential erosion, of U.S. industrial capabilities. Surprising to this researcher was that significantly more information was available through periodicals then directed studies. This supports comments in the literature that only ad hoc studies, vice comprehensive studies, have been

completed in many industrial base areas. While none of the literature reviewed discussed test equipment specifically, this was a possibility that had been foreseen early in this project.

The first changes in the size of the study came with the realization that it would not be practical to look at several missile programs. Then, even with the selection narrowed to one program and one year of usage data for continuing operations, the sheer magnitude of data to be examined was prohibitive. It was not possible for one researcher to adequately perform the desired depth and breadth of this project. Specifically, it was not possible to contact all the suppliers, and with very few exceptions, it was not possible to go beyond the first tier of suppliers.

The unanticipated situation that forced Texas Instruments to curtail much of its support removed considerable expertise and corporate knowledge. This was exacerbated by the volume of data to be investigated and the lack of resources, both human and communications, available to this researcher.

On several occasions, component part numbers were not recognizable. This was the result of two common problems: first, the field width of the manufacture's part numbers was not sufficient to allow adequate digits; and second, the part number was not at all recognizable to the supplier. The former was a shortcoming (in regard to this study) in the

information system software, the latter was assumed to be predominately data entry errors.

On those occasions where part numbers were not usable, attempts were made to identify components by purchase order numbers. This was successful only once. It failed due to the age of the data. While less than two years old, and in many instances less than one year old, none of the applicable suppliers maintained purchase order information in a readily accessible fashion beyond six months to one year.

In only one instance did anyone refuse to lend assistance over the telephone. This researcher thought this to be significant. In light of company proprietary information and agreements not to divulge information to third parties, more resistance was expected.

As presented, the research methodology was an evolving process that took a form significantly different than anticipated by the researcher. The data collected, and an analysis of that data, are presented in the following chapter.

V. CASE STUDY FINDINGS

A. BACKGROUND

The purpose of this study was to examine a selected area within the broad concern of foreign sourcing and the industrial base. The data presented in this chapter reflect that developed in a case study performed to test the extent to which foreign sourced components are used in U.S. manufactured test equipment and the implications of such sourcing. The scope of this study was limited to that of special test equipment (STE) used in the production manufacturing process.

The data that follow represent a segment of one year of sustaining operations of the HARM missile program's production STE. As used here, sustaining operations are those material requirements that reflect the repair, upkeep and modification to production STE already in service. The most recently completed project for which material usage data were available was the contract period November 1988 to October 1989. Texas Instruments Inc., is the prime, sole source, contractor for the HARM missile. The production site is located in Lewisville, Texas.

With few exceptions, production STE employed by the manufacturer is owned by the government. When utilizing government owned equipment, the manufacturer must maintain a variety of information concerning use and support of that

equipment. That information provided the foundation of this study.

B. PRESENTATION OF THE DATA

A computer generated list of components and materials used to support the HARM missile production STE through this contract period contained over 1800 line items. The quantities for each line item were typically one or two but in some instances were as many as 100 or 200. The large quantity items were hardware items such as washers and screws. The information provided for each line item included: Texas Instruments and vendor part numbers, purchase order number, supplier and quantity ordered. Materials were obtained from approximately 260 suppliers. These suppliers included both manufacturers that sold directly to Texas Instruments and vendors that represented a variety of manufacturers.

Of approximately 1800 line items represented in sustaining operations, over 170 individual part numbers had multiple entries. This reflected two or more purchase actions for a specific part number. An additional 80 line items were repair charges, set up charges and calibration charges. In effect, the multiple entries and service charges reduced the number of line items, or actual material/component part numbers required, by several hundred.

Of the 260 suppliers associated with supporting these continuing operations, 62 were contacted. These 62 suppliers

represented approximately three-fourths of the individual items purchased. In an attempt to determine the item nomenclature and place of manufacture, 39 of the 62 contacted were capable and willing to provide the requested information to the best of their ability. The ability of the suppliers to furnish additional information depended to a great extent on the completeness and accuracy of the data supplied by the researcher.

There were 280 different part numbered items identified by suppliers as materials and components supplied to Texas Instruments in support of HARM missile production STE for the period November 1988 to October 1989. Table V-1 presents a sampling of those materials and their countries of origin.

Of the 280 part numbers that were identified, three were clearly determined to have originated outside the United States. Four other components were routinely manufactured in both the U.S. and several Pacific Rim Countries and could not be further isolated with the data provided. Tables V-2 and V-3 list the known and possible foreign sourced components. Rare earth metals, such as columbium and selenium, are not listed although historically, these types of materials have been recognized as foreign sourced.

TABLE V-1

SAMPLE OF ITEMS USED IN CONTINUING OPERATIONS

Item	Country of Manufacture
Delrin plastic	U.S.
Teflon rod	U.S.
AC current sensor/controller	U.S.
Single axis motion controller	U.S.
Cable assemblies	U.S.
Cable connecters/adapters	U.S.
Wide band amplifier	U.S.
Polyvinylidene tubing	U.S.
Polyester sleeve	U.S.
Micro wave amplifier, 2-8 GHz	U.S.
Micro wave amplifier, 4-8 GHz	U.S.
Micro wave amplifier, 12-18 GHz	U.S.
Open reel computer tape	U.S.
Custom software	U.S.
Pneumatic solenoid/valve	U.S.
Voltage controlled attenuator	U.S.
Specialty hardware (nuts, studs)	U.S.
Power supply	U.S.
Programmable phase shifter	U.S.
Hydraulic fixture	U.S.
Blower assembly	U.S.
Power divider	U.S.
RF coupler	U.S.
Accelerometer	U.S.
Gasket, stainless steel	U.S.
Gasket, nickel	U.S.
Traveling wave tube	U.S.
Low pass filter	U.S.
Coaxial transfer switch	U.S.
Relay	U.S.

TABL V-1 (CONTINUED)

Item	Country of Manufacture
Low voltage board	U.S.
Precision wirewound resistor	U.S.
O-Ring	U.S.
LED	*
Rectifier	*
Instrument low power amplifier	Thailand
Switch	Japan
Knob	Japan
Rare earth components	**

* Items were identified as manufactured in U.S. or Malaysia. Further determination was not possible with data provided. Both locations are common sources.

** Specific applications were not included. However, one manufacturer indicated that rare earth components used in their products, originate overseas.

TABLE V-2

ITEMS KNOWN TO BE MANUFACTURED OUT OF THE U.S.

Item	Country	Quantity	Unit Price
Knob	Japan	1	$ .84
Switch	Japan	1	$18.80
Low Power Amp.	Thailand	1	$21.62

TABLE V-3

ITEMS OF UNKNOWN U.S./PACIFIC RIM ORIGIN

Item	Quantity	Unit Price
IC display Driver	1	$ 4.00
Lamp Assembly	1	$17.50
LED	1	$ 6.00
Rectifier	1	$28.00

C. ANALYSIS OF THE DATA

In absolute terms, the data presented would indicate that three of the 280 items, or 1.07 percent of the components sampled, were obtained from foreign sources. If the additional four components of possible foreign sourcing are considered, 2.5 percent of the components may have been foreign sourced. One could interpret this to mean few foreign sourced components are used in this particular production STE. Of the items known to have been manufactured overseas, only one item, the low power amplifier shown in Table V-2, did not appear to have an equivalent produced in the U.S. However, caution must be exercised when viewing these figures. There are several concerns that may skew the findings as presented.

First, the usage data reflect only those materials required to maintain or modify existing equipment. A similar relationship might be assumed to exist between those materials used in the initial construction and continuing operations, but no factual relationship was attempted in this study.

A second issue was that several of the vendors supplying the greatest quantities of materials did not respond with information concerning the place of manufacture of the materials they provided. There is the possibility that the larger vendors, with greater resources and possibly more global networks, will purchase more from foreign sources than a smaller, regional vender. If that is true, it follows that the materials they sell will be representative of the original

sources. In this study a significant number of the responding vendors and manufacturers that sell to Texas Instruments are located in the same geographical region as the HARM missile production site. It was not possible to calculate any error that may have been induced by the non-responsiveness of several large vendors.

Throughout the study there was occasional difficulty in identifying individual part numbers. These problems surfaced in two ways: one, the part number was not at all recognizable by the indicated supplier; and two, the part number was recognizable to some extent, but appeared to have digits transposed or missing.

In the first situation, where no identification was possible, there was no alternative but to discard that item. Assuming the ratio of foreign versus domestic supplied components not able to be identified, is similar to the ratio of those that were identified, discarding these has little or no effect on the final balance between U.S. and foreign sourced items.

In the second situation it was normally possible to make use of the data. For example; if it was known that the item was one of two amplifiers, and they were both manufactured in the same location, but a missing suffix on the part number only precluded determining which of two frequency ranges it was, that item was counted.

No materials in this study were found to have been purchased directly from a foreign source by Texas Instruments. In those instances where vendors purchased from foreign sources, the vendor was asked to provide a reason for the foreign versus U.S. produced material. Only one item, the low power amplifier shown in Table V-2, was addressed specifically. The reason given was "economic." The researcher takes this to imply that the item may be available elsewhere but the foreign source was less expensive.

In the other instances of foreign or possibly foreign sourced materials, general reasons were provided. The two reasons given were price and availability, with price being the predominate of the two. Vendors purchasing materials from foreign sources indicated that the materials they buy are typically low technology, high volume, common items in which a foreign producer can take advantage of economies of scale and a large semi-skilled work force. Availability was an issue only because the types of items just discussed are not produced in great quantities in the U.S. In each instance where it was discussed with a vendor, the vendor was confident that a U.S. source or capability existed should the foreign supply be disrupted.

In general terms, and not necessarily directly related to the components identified in this case study, vendors contacted indicated countries such as Malaysia, Taiwan and Mexico as the primary sources of foreign materials that would

be used in STE. When used, the products of the Pacific Rim countries include common electronics components, and simple assemblies and subassemblies. Mexico was utilized mostly for non-complex assembly work. It is not unusual for a U.S. manufacturer to provide materials to a Mexican facility for assembly or partial assembly, after which they are returned to the U.S. for final assembly and testing.

It is the belief of the researcher that despite the potential influences discussed above, these data present an accurate picture of the overall trend in the mix of U.S. and foreign sourced materials used in the production STE of this case study. This researcher does not believe that the data are extensive enough to support a specific claim that foreign sourced items represent 2.5 percent or less of all materials used in continuing operations in support of STE.

These data also support the opinions and judgments of several professionals involved in the manufacture and support of production STE. Early in the research performed to complete this study, these industry representatives were contacted in a search for information concerning earlier studies in this field. While no studies were identified, each person, based on personal experience, suggested that few foreign sourced components would be found in this type of special test equipment.

Responses to the research questions, a summary and areas for further study are provided in the following chapter.

VI. CONCLUSIONS

A. RESTATEMENT OF THE OBJECTIVE

The object of this study was to examine the industrial base issue of foreign sourcing. The area of focus was that of manufacturing production special test equipment (STE). The intent was to determine the extent of foreign sourced materials and components in production STE, what those materials are, and what the implications are.

In general terms, test equipment is equipment used to test, measure and diagnose other equipment or products. There are hundreds of types of test equipment with thousands of variations. To narrow the scope of this study, only production special test equipment was examined. This test equipment is designed for a specific and often unique application in a production process.

The findings were developed by extracting material usage data for one year of continuing operations of the HARM missile production STE used by Texas Instruments. Continuing operations were those requirements necessary to maintain, modify and provide general support to existing equipment. Of over 1800 line items provided by approximately 260 suppliers, approximately 280 line items provided by 39 suppliers were identified and the country of origin determined for each.

The statements that follow are based on an analysis of the cited data, opinions of industry representatives, and qualifications as stated.

B. RESEARCH QUESTIONS

This section restates and addresses the research questions presented in Chapter I.

Primary research question: To what extent are the components and materials used to manufacture special test equipment obtained from foreign sources and what are the implications of reliance upon foreign sources?

Because of the previously stated restrictions the results of this study are not statistically conclusive. However, when confined in scope to the manufacture of production STE, and according to the data developed in the case study, there was little use of foreign sourced materials and components. This conclusion was anticipated by the professional opinion of several industry representatives specializing in production STE.

The implications of relying on foreign sourced materials can not be answered as stated, since no instances were discovered in the case study or the literature review except for rare earth metals. Reliance on rare earth metals is a well documented fact and is principally compensated for through stock piling.

Concerning the potential inability to continue production operations should the flow of these few foreign sourced items stop, industry representatives did not foresee a problem. First, most foreign sourced materials in this equipment were not complex and are well within the capabilities of U.S. manufacturers to reproduce.

Secondly, it is not uncommon, regardless of the original source, for a required replacement item to be no longer available when needed. When this happens, a suitable substitute is used if available. If not, the applicable portion of the STE is redesigned around a component that is available. Another way Texas Instruments minimized the impact of such a shortage was by stocking a significant number of repair pieces. It maintains a stock of over 4700 purchase part items, purchased with HARM project dollars and dedicated to the support of HARM production STE. Texas Instruments also maintains an overhead equipment and support system to support their equipment not contractually dedicated to a given project.

Should a source of materials go away, representatives indicated sufficient time was available to locate or develop another. It must be remembered that material requirements for production STE, which is relatively static equipment, will be significantly less than for an actual production item going out to customers.

Secondary research question: What are the STE components and materials?

When components and materials are obtained from foreign sources for use in the manufacture of production STE, they were limited to rare earth metals, low technology, high volume electronics components and simple assemblies and subassemblies.

Secondary research question: What components and materials are obtained exclusively from foreign sources, or, in addition to domestic sources?

Beyond rare earth metals, only one component was found to be obtained exclusively from foreign sources in the manufacture of production STE. A low power amplifier was obtained from a foreign source without a direct equivalent also being obtained from a U.S. source. But based on the types of items obtained from U.S. sources, it is highly improbable that a compatible item is not available from domestic sources.

Several items were found to be available and obtained from both foreign and domestic sources. These included knobs, switches and LED's. Some simple, low-level assembly work was done in Mexico and various Pacific Rim countries.

Secondary research question: What are the principal reasons components and materials are obtained from foreign sources?

Although the sample size is considerably smaller than desired, the principal reasons those production STE components and materials sampled were obtained from foreign sources are economics and availability. The materials obtained from foreign sources are predominately high volume, low technology items produced in countries with a large semi-skilled work force. Typically their operating expenses are low and they produce large volume items to take advantage of economies of scale. For reasons not determined in this study, domestic manufacturers often do not compete in these markets.

At the site of the production STE, cost of a needed component is not normally an issue. There are two reasons for this. First, since individual component consumption is low, the time and expense of searching for a less expensive item will quickly surpass any savings. Second, a disrupted production line can be far more costly from the delay searching for a less expensive replacement component than the cost savings of a cheaper replacement.

Availability is somewhat deceiving. As previously stated, items that are more readily available from foreign sources are so because they are high volume, low cost production items. U.S. manufacturers do not produce these in significant quantities. However, there are no indications that the U.S. does not possess the capability to produce these items. Again, the exception is rare earth metals where the U.S. is

not likely to achieve independence unless future technology reduces the requirement to use them.

C. SUMMARY

Based on a selected analysis of data, it was discovered that there is not a high incidence of foreign sourced materials and components in the HARM missile production STE. It is also concluded that the production STE examined is representative of production STE that would be found throughout much of industry. Both of these opinions are based on analysis of the HARM missile production STE data and the professional judgments of industry representatives.

The findings of this study must be qualified for several reasons. First, the study examined production STE on only one of thousands of production lines throughout the country. On that production line, only one year of continuing operations were examined. No data were examined of all components that comprised any single piece of equipment.

The use of data from material usage and purchase actions to determine the extent to which foreign sourced components and materials are utilized proved to be a reasonable approach. It would have been preferable to have gathered data by first using drawings to identify components, backtracking through engineering and possibly purchasing to determine the suppliers, and then through the suppliers to determine the components' origin. However, this would require significant

funding resources to pay for such a study. It would also have been preferable to have had the resources to explore a larger sampling of suppliers and components, and to have been able to further reduce assemblies to their component parts.

The hypothesis that led to this research was that as much as 30 percent of the components in U.S. test equipment are foreign sourced. This study does not provide sufficient data to dispute or support that statement. As discussed, the hypothesis does not hold true for the sample of production STE examined here. The hypothesis may be true for instances of other test equipment.

As stated earlier, there is a wide variety of types of test equipment. Unlike the production STE of this study, which is essentially custom built, many types of test equipment are mass produced. These are types of test equipment that have a wide range of generic applications. Examples include voltage meters, current meters, frequency counters and frequency generators. Test equipment of this type is common and purchased "off the shelf." It is used by television and radio repair shops, scientific laboratories, NASA and a myriad of defense contractors and military units. Variations are used by hobbyists in their basements, and major corporations when maintaining their production STE.

It is in these general types of test equipment that the researcher suspects a large portion of foreign sourced components may be used. These pieces of test equipment are

relatively simple and produced in large quantities. Their production and component demand criteria might well meet those which would encourage foreign sourced materials. If other countries, the Pacific Rim countries specifically, continue to develop their production capabilities for high volume, low technology items, while the U.S. manufacturers concentrate on high technology items, it follows that the concentration of foreign sourced components in these types of test equipment will be high and continue to grow.

D. RECOMMENDATIONS FOR FURTHER RESEARCH

The following are suggested areas of future research. Some do not specifically deal with production STE, but were topics uncovered in gathering research for this thesis.

Readdress this same area of study, i.e., foreign sourcing and manufacturing of production special test equipment. The literature review and contact with industry representatives failed to uncover earlier studies. This study, which was very limited, fails to offer absolute, conclusive evidence that foreign sourced materials are not a potential area of concern for the U.S. manufacturing industry. More than one production line, and a complete breakout of all components of STE should be made. A requirement for such a study will be sufficient, dedicated resources.

Determine the extent and implications of foreign sourced materials in common, widely used U.S. test equipment. In a

selected field, is the United States an industry leader or follower? What is the future of a selected test equipment industry and how will that affect the industry it supports?

The U.S. is reducing its export deficit in low technology manufactured goods and loosing its trade surplus in high technology manufactured goods. This presents several questions: Where does the U.S. stand in global competition? Where is it going? Why? What will be the impact on tomorrow's industrial base? Should industry be concerned? What role can or should the government play?

Is America's perception of increasing reliance on foreign sourced materials accurate? An article in the Harvard Business Review by Robert B. Reich, titled "Who Is Us?", discusses the global market place and global corporations. The statistics on imports and exports may be deceiving. For example, IBM Japan, with over 18,000 employees and annual sales in excess of $6 billion, is one of Japan's leading exporters of computers. [Ref. 27] What portion of U.S. imports are actually products of U.S. companies operating overseas? What would the consequences be if the U.S. did not actively participate in these markets?

Does the U.S. need a Ministry of International Trade and Industry or something like it? The literature review revealed that there is some consensus that the U.S. would benefit from an organization similar to Japan's MITI. In many ways the Department of Defense is acting as the nation's MITI. With

concerns for the defense industrial base and ultimately the nation's industrial base, DoD is targeting selected areas for research and development, and even preservation of U.S. capabilities. Is DoD the best agency to preform this task? Possibly it should fall within the Department of Commerce. Within industry there is a tremendous number of trade associations already in existence. Is it possible or even desirable for them to establish a nongovernment office to safeguard America's industry? Another approach might be a government/industry association to review and evaluate U.S. technologies and capabilities. Ultimately they would determine where concentration was needed and work to develop those areas.

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